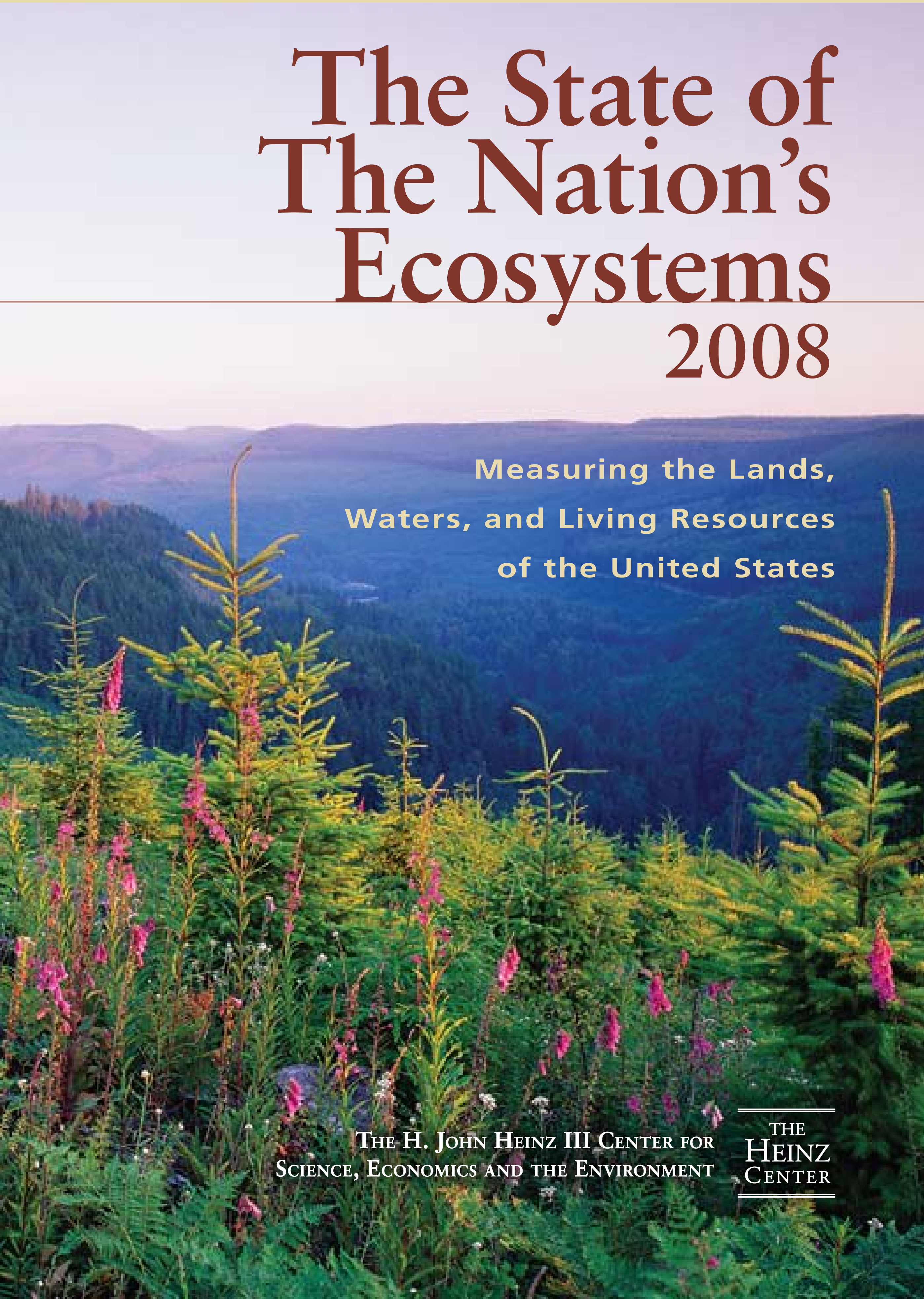
Highlights

The State of The Nation's Ecosystems 2008



Measuring the Lands, Waters, and Living Resources of the United States

THE H. JOHN HEINZ III CENTER FOR SCIENCE, ECONOMICS AND THE ENVIRONMENT

THE HEINZ CENTER

About the Heinz Center

At the crossroads of science and environmental policy, the Heinz Center brings leaders together from business, government, academia, and environmental groups to brainstorm solutions that are both scientifically and economically sound. Founded in 1995 in honor of Senator H. John Heinz III, the Center was established with the guiding philosophy that only by working together can we solve today's environmental challenges and leave the world a better place for generations to come.

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The State of The Nation's Ecosystems 2008

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About This Report

This report is derived from *The State of the Nation's Ecosystems 2008: Measuring the Lands, Waters, and Living Resources of the United States,* which is published by and available from Island Press at www.islandpress.org. It also draws on concepts presented in two other Heinz Center reports: *Environmental Information: A Road Map to the Future* (2008) and *Filling the Gaps*: *Priority Data Needs and Key Management Challenges for National Reporting on Ecosystem Condition* (2006). Thus, this report merges work undertaken by a very large group of partners and collaborators (*The State of the Nation's Ecosystems 2008*) with concepts and ideas developed by the Heinz Center as the steward of the State of the Nation's Ecosystems project. Copies of this *Highlights* report are available free of charge from

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This report is derived from *The State of the Nation's Ecosystems 2008: Measuring the Lands, Waters, and Living Resources of the United States.*

About the Paper

Printed on Accent Opaque 80, White, Smooth. This paper was made within the largest conservation area in the lower 48 states—the Adirondack Park of northern New York. The 6-million-acre park is a mosaic of public and private ownership, protected wilderness, historic communities, working forests, and International Paper's Ticonderoga mill. It is also home to purple crowberry, tamarack, pitcher plant, bear, moose, pine marten, spruce grouse, loon, peregrine falcon, northern harrier, and bald eagle. The trees come from forests that have been managed responsibly for more than 110 years and are harvested according to the principles of the Sustainable Forestry Initiative® and the Forest Stewardship Council®, third-party certification standards ensuring the continual planting, growing, and harvesting of trees while protecting wildlife, plants, soil, and water quality.

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State of the Nation's Ecosystems Project: Design Committee, Other Participants, and Funders

Design Committee

The Design Committee provides strategic guidance and decision making for the State of the Nation's Ecosystems project. This role includes active decision making and monitoring, as well as oversight of project activities to assess their conformity with the project's strategic directions.

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Other Participants

Hundreds of other participants served in working groups, workshop groups and ecosystem contact groups to develop and refine the indicators; others served as external reviewers. A full listing of 2002–2008 participants can be found on pages vi–xiii of the main report, *The State of the Nation's Ecosystems 2008*.

Funders

The State of the Nation's Ecosystems is supported by a balanced mix of public and private funds. Half of the project's current annual budget is provided by corporate and foundation sources and individuals. The remaining funds are provided by several federal agencies, whose participation was organized by the White House Council on Environmental Quality and the Office of Science and Technology Policy. Nonfederal funds account for approximately 45% of the project's overall budget since its inception in 1997. We are deeply grateful to the following entities for their financial support of the State of the Nation's Ecosystems project:

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U.S. Environmental Protection Agency

Information Matters

Americans care deeply about what is happening to the lands, waters, and living resources of our nation. Increasingly, the media spotlights serious debates in our society over how best to address environmental challenges. These include such thorny questions as how to allocate limited water resources, manage fish and wildlife populations, accommodate and shape suburban and rural development, and maintain vibrant farm and forestry economies. The outcomes of such debates have vital implications—not only for the condition of the nation's ecosystems, but for people and their pocketbooks as well.

It may be unrealistic to expect simple answers or broad agreement about how to resolve such complex issues. However, Americans rightly expect that their information-rich society can provide reliable and up-to-date answers to the fundamental underlying questions: *How is the environment changing? Are the problems we face getting better or worse? Where? What new challenges are arising? Are government or private programs dealing effectively with these challenges?*

As the Heinz Center's State of the Nation's Ecosystems project demonstrates, however, it is not yet possible to provide answers to many of these basic questions. The nation's environmental monitoring and reporting enterprise—on which *The State of the Nation's Ecosystems 2008* rests—is not matched to the problems, concerns, and decision-making needs of the 21st century. Despite significant investment and a cadre of highly skilled practitioners, information on the state of America's environment is often fragmented, overly technical, not comparable from one place to another, or simply unavailable. This lack of systematically organized, high-quality, scientifically credible, and readily and routinely available information hampers the development of effective responses to environmental challenges.

The core premise of the *State of the Nation's Ecosystems 2008* is that American citizens should have access to periodic, high-quality, nonpartisan information on the state of our lands, waters, and living resources. Attempting to manage our vast and valuable natural resources without this information is like driving a vehicle with the front and rear windshields largely obscured. Without being able to assess at a glance where we are, where we have been, and the direction we are going in, we as a society are unlikely to engage in the type of informed discourse needed to reach effective decisions on important environmental issues. Climate change, added to the panoply of existing pressures on the nation's ecosystems, will modify the nation's ecosystems significantly over the coming decades. Thus, ensuring the delivery of sound, unbiased, integrated information to guide the nation's response is of paramount importance.

Building Trust through Partnerships

Since 1997, federal agencies, foundations, corporations, and individuals have supported the Heinz Center's State of the Nation's Ecosystems project to identify and report on a modest number of important trends in the condition and use of our lands, waters, and living resources. In a novel initiative originally commissioned in 1997 by the White House Office of Science and Technology Policy and more recently supported by the Council on Environmental Quality, The Heinz Center has convened hundreds of experts from businesses, environmental organizations, universities, and federal, state, and local governments. These individuals were charged with identifying key aspects of our nation's coasts and oceans, fresh waters, forests, farmlands, grasslands and shrublands, and urban and suburban areas that should be tracked through time to provide a consistent and comprehensive view of trends in each of these ecosystems and the national as a whole.

BOX 1 State of the Nation's Ecosystems Design Principles

Over the years, five main design principles have guided the development of the *State of the Nation's Ecosystems* reports:

- ***Focus on condition and trends.*** Describe important characteristics and trends for the nation's lands, waters, and living resources, rather than identifying the causes or cures for problems (or perceived problems). Thus, the reports document the ultimate ***outcome*** of all such activities—the resulting condition of the ecosystems and the goods and services they provide.
- ***Be relevant to contemporary policy issues.*** Present information that is relevant to and can be used by decision makers and opinion leaders. To this end, the indicators are designed to provide a "big picture" view that is succinct and strategic rather than exhaustive.
- ***Select and report on an unbiased and balanced array of indicators.*** Provide information that informs policy, but do not endorse particular positions or outcomes, and avoid, as far as possible, political bias, the use of inflammatory or "hot button" language, or reference to subjective benchmarks. The report's consultative development process balances value-driven choices about what features of ecosystems should be reported with scientific rigor.
- ***Report only data that meet high standards for quality and coverage across the nation and through time.*** The reports are based on the most current scientific knowledge and a rigorous peer-review process.
- ***Update periodically and learn from experience.*** The reports are dynamic "works in progress," not a limited-time effort. Periodic and ongoing updates are needed to supply users with the most recent data and to allow for incorporation of scientific advances and enhancements to the nation's monitoring and reporting infrastructure. Where available data fail to meet quality and coverage criteria, the relevant indicator is left blank and the data shortcomings that led to its omission are explained.

Crucial to the success of this work is the Center's strategy of ensuring that key interest groups are directly involved in decisions about indicators in which they have a stake. While participants in the report's design process often disagreed about specific policy and management matters, the Heinz Center's transparent, inclusive, science-heavy approach to indicator development was successful in gaining consensus among these parties about what ecosystem conditions should be tracked over time and how to present these findings without bias or agenda. See Box 1 for a summary of the project's design principles.

Ecosystem Indicators—a Tool for Understanding Change

The State of the Nation's Ecosystems 2008 seeks to focus society's attention on key aspects of ecosystems (Box 2), much as economic reporting selects key features of the economic landscape, such as unemployment and inflation, in order to gauge overall economic progress and monitor trends. Doctors do much the same by checking blood pressure, cholesterol, and other key health indicators during annual checkups.

Well-designed and carefully selected indicators are needed to serve as practical, economical, and responsive tools for tracking ecosystem changes. The term "indicator" is used in this report to refer to a specific, well-defined, and measurable variable that reflects some key characteristic that can be tracked through time to signal what is happening within and across ecosystems. Indicators may include biological, physical, and chemical measurements. Besides communicating the current condition, or "state," of an ecosystem to policymakers and the public, indicators can also be used by land managers to determine if objectives are being met or by scientists to detect unexpected changes in ecosystems.

The key indicators reported in *The State of the Nation's Ecosystems 2008* reflect the *combined* effects of a broad range of natural processes and human "pressures," including regulatory actions and protective measures to which the ecosystems have been subjected. By design, these indicators are not

BOX 2 What Are Ecosystems, and Why Does This Report Focus on Them?

The *State of the Nation's Ecosystems 2008* focuses on *ecosystems*—dynamic, interacting complexes of living organisms and their nonliving environment within a defined area. Ecosystems produce important goods and services, provide fundamental life-support services for people and other organisms, and have intrinsic value to many people as well. Because they are shaped by many forces, ecosystems reflect the ultimate *outcome* of all human and natural influences combined.

Often used to describe specific places—"the greater Yellowstone ecosystem" or "the Chesapeake Bay ecosystem"—*ecosystem* can also be used to denote broad groups of specific places that share important common features. In this report, we use the term in this latter sense, which is in fact a shorthand way of saying *ecosystem types.* In this usage, a Southeastern pine wood and an old-growth Pacific Northwest forest are both "forest ecosystems," a term that recognizes that despite many differences, the two systems are alike in many ways, *and* that many laws, policies, and practices apply to these forest ecosystems and not, for example, to farmlands. This report thus focuses on six major *ecosystem types:* coasts and oceans, farmlands, forests, fresh waters, grasslands and shrublands, and urban and suburban landscapes. In addition to ecosystem-specific indicators, *core national indicators* provide a "big picture" view of the status of all the nation's ecosystems combined.

We use the term *ecosystems*, as distinct from *environment,* to highlight the focus on lands, waters, and living resources. Although the two words are often used interchangeably elsewhere, we use the term *environment* to encompass issues such as human health concerns, energy use, resource extraction, and waste management. This report focuses on *ecosystems* because of their importance in both environmental (broadly defined) and economic policymaking, and to complement other environmental reporting.

intended to point at specific causes—often a scientifically complex and politically contentious affair. *The State of the Nation's Ecosystems 2008* reports on species at risk of extinction, for example, but does not attempt to parcel out responsibility among the many possible causes. Over time, the ecosystem changes tracked by the indicators will stimulate research to identify key causes and potential responses, but these are not the province of *The State of the Nation's Ecosystems 2008*.

By noting trends in ecosystem condition, policymakers can assess the mix of goods and services that are or may be received from ecosystems, evaluate tradeoffs, and make informed choices about the allocation of benefits among the competing—and rapidly increasing—demands that people are placing on ecosystems.

Environmental policy and management programs often target specific aspects of the environment—such as discharges of wastes or proposals for resource extraction. Other programs manage activities within the boundaries of federal agencies, states, or local jurisdictions. However, as more people recognize the importance of managing natural systems on an ecosystem scale, the need for information that provides a broad and integrated context also grows. Because of the strong scientific underpinnings of the indicators presented in *The State of the Nation's Ecosystems 2008,* their lack of bias, and the broad support for their development, decision makers in both the public and private sector can rely on them as a foundation for science-based dialogue and public discourse about environmental priorities and resource allocation.

The suite of indicators is intended to allow readers to look at ecosystems at different scales, although current limitations in available data make this possible only for certain ecosystem types. For example, we report that cropland acreage has declined nationwide, but regionally some river basins are losing cropland and some are stable. Each view provides a different set of information about overall ecosystem condition, and each is relevant to a different set of policy and management decisions. As the nation's environmental monitoring and reporting systems expand and move toward greater harmonization, such multiscale analyses will become possible across even more ecosystem types.

The State of the Nation's Ecosystems 2008: Prototype for a National Reporting System

The purpose of the Heinz Center's State of the Nation's Ecosystems project is to lay the groundwork for periodic, high-quality, nonpartisan reporting on the condition and use of U.S. ecosystems, the goal being a stable set of broadly accepted and well-tested indicators. The 2008 report builds on the successful 2002 *State of the Nation's Ecosystems*[*] report in moving in this direction. As part of the evolutionary design of the reports, many indicators were improved and refined between 2002 and 2008, but the indicators are largely consistent through both reports, providing as rich a sense of trends as possible. The reports' organization is also consistent across the two volumes: both reports describe an established set of ecosystem characteristics across the nation's six principal ecosystem types—for example, there are separate indicators for biological communities in coasts and oceans, farmlands, forests, fresh waters, grasslands and shrublands, and urban and suburban landscapes—and include *core national* indicators that describe trends across all ecosystems combined. Another important feature continued in this second report is the highlighting of key indicators for which data are not available at the national level.[†]

Key Ecosystem Characteristics

The indicators in *The State of the Nation's Ecosystems 2008* fall into four categories:

- **Extent and pattern** indicators describe the area or length of ecosystems and how they are intermingled across the landscape. Examples: area of wetlands, length of rivers and streams, proximity of croplands to residences.
- **Chemical and physical characteristics** indicators report on nutrients, carbon, oxygen, contaminants, and key physical trends. Examples: the amount of nitrogen delivered by major rivers to the nation's coastal waters, soil erosion on croplands.
- **Biological components** indicators provide information on the condition of plants, animals and living habitats. Examples: species at risk of extinction, the percentage of species in a region that are not native.
- **Goods and services** indicators provide information about things people derive from the natural world and about less easily measured benefits, called "natural ecosystem services." Examples: amount of timber harvested, participation in outdoor recreation, pollination.

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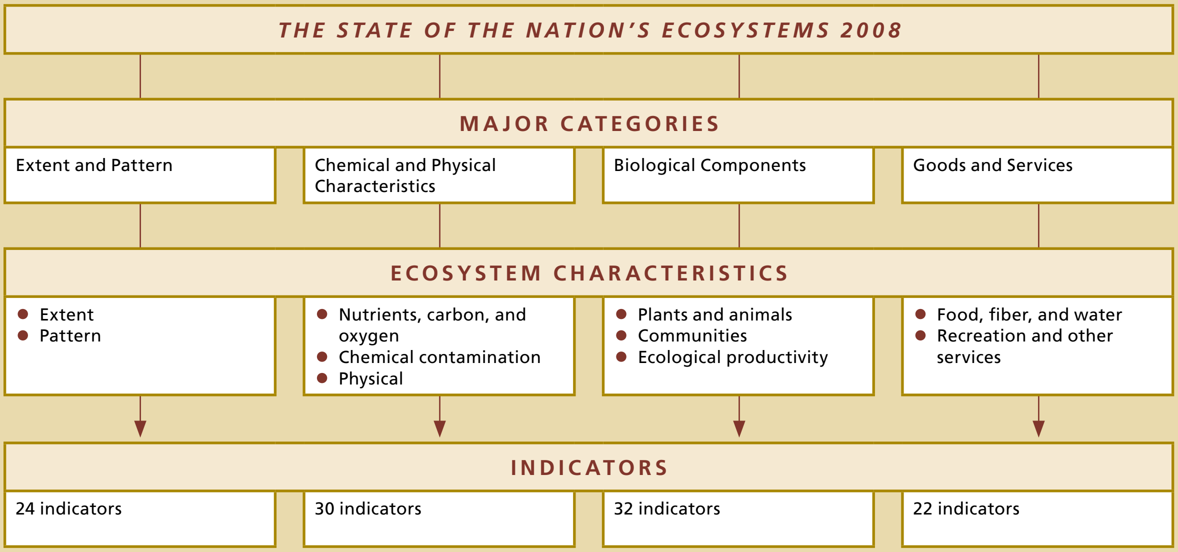
* The Heinz Center. 2002. *The State of the Nation's Ecosystems: Measuring the Lands, Waters, and Living Resources of the United States.* Available at www.heinzcenter.org/ecosystems or through Cambridge University Press at www.cambridge.org.

† See the Heinz Center's *Filling the Gaps* report (2006) and the Government Accountability Office's *Environmental Information: Federal Programs That Support Environmental Indicators* (2005, GAO-05-376).

Together, these 108 strategically chosen indicators (see The Indicators at a Glance, page 9–11) describe major aspects of condition and use for each of the nation's six principal ecosystem types (coasts and oceans, farmlands, forests, fresh waters, grasslands and shrublands, and urban and suburban areas) and for the nation as a whole (see Figure 1). They reflect a wide range of ecological trends, which makes them relevant to a wide array of environmental issues.

FIGURE 1 Categories, Characteristics, and Indicators



What's New in 2008—Refined Indicators, More Data

Work on the 2008 report was driven by the need to complete and strengthen the set of core national indicators, to improve the degree of consistency in how the same or similar ecological phenomena are reported in different ecosystems, and to reduce the number of indicators in need of further definition.

Of the 108 indicators in the 2008 report, six are new since the 2002 report and 57 have been refined or redesigned. Refinement or redesign encompasses inclusion of new metric components, changes in the computation of metrics, changes in presentation of regional data, and further technical development of an indicator that remains undefined. See Box 3 for the criteria used to decide whether data would be included in the report.

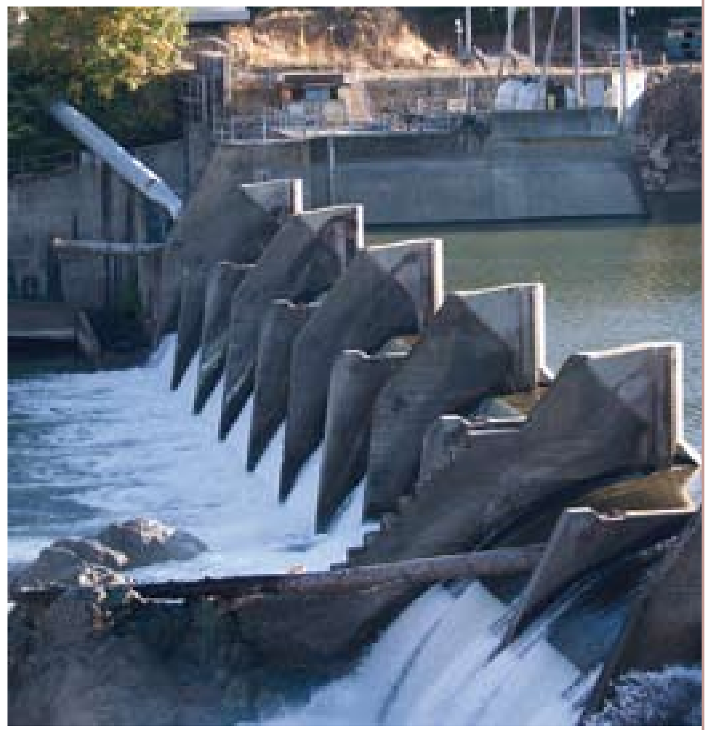
BOX 3 Criteria for Data Inclusion

The *State of the Nation's Ecosystems* indicators are intended to serve as prototypes of future national indicators of the condition and use of our nation's ecosystems. Thus, rather than designing the indicators around available data, participants identified key indicators that should be tracked, then identified whether data were available for reporting.

Very briefly, data must meet three criteria to be included in the reports:

- The data must approach "national" in scale (that is, data for only a few areas are not sufficient to provide a national perspective)
- There must be a reasonable likelihood that the data will be collected and reported in the future (that is, one-time research data are not an adequate basis for long-term national reporting)
- The data must be scientifically credible (that is, they must be judged by the professional community that uses these data as adequate to make the kind of national inferences found in this report).

The 2008 report presents more data than the 2002 report (see Table 1). Of the 108 indicators in the 2008 report, 68 (63%) have adequate data to report on a national level, an increase over the 58 (56%) indicators for which adequate data were available in 2002. In addition, the number of indicators for which multiyear trends are reported rose from 31 in 2002 to 41 in 2008, and the number for which an established reference point was included (for example, comparing concentrations of nitrogen in water to the drinking water standard) rose from 14* to 20. Data newly included in this 2008 report include data from new monitoring efforts, data that existed but that had not been sufficiently aggregated or checked for quality to be included in the 2002 report, and data that are included for the first time as a result of indicator development efforts.



Of the 68 indicators for which adequate data are available in this report, 36 have all the data required and the remaining 32 have some data gaps (see Table 1 and the section on Data Gaps and Challenges, page 29). These gaps may be regional (data are available for part but not all of the country) or they may be topical (data are available on some but not all components of an indicator).

TABLE 1 Summary of Changes in Data Availability, 2002 to 2008

DATA AVAILABILITY	2002			2008		
	%	NUMBER		%	NUMBER	
All data	32	33	58	33	36	68
Partial data	24	25		30	32	
Insufficient data	30	31		26	28	
Undefined indicator	14	14		11	12	
All Indicators	**100**	**103**		**100**	**108**	
Indicators with Trends	31			41		
Indicators with Reference Points	14			20		
Indicators with Current Data Only	16			27		

* This figure was reported as 11 in 2002 because three indicators were incorrectly categorized at that time.

The Indicators at a Glance

This table serves as an overall guide to *The State of the Nation's Ecosystems 2008*. It lists all indicators in the report and shows both the indicators used to describe a specific *ecosystem type* (in the columns) and the indicators used to describe specific *ecosystem characteristics* (in the rows). Indicators added or modified since the 2002 *State of the Nation's Ecosystems* report are also identified.

The Indicators at a Glance

	Core National Indicators	Coasts and Oceans	Farmlands
EXTENT AND PATTERN			
Extent	• Ecosystem Extent*	• Coastal Living Habitats • Shoreline Types	• Total Cropland* • The Farmland Landscape*
Pattern	• Pattern of "Natural" Landscapes†	• Pattern in Coastal Areas‡	• Proximity of Cropland to Residences† • Patches of "Natural" Land in the Farmland Landscape†
CHEMICAL AND PHYSICAL CHARACTERISTICS			
Nutrients, Carbon, and Oxygen	• Movement of Nitrogen* • Carbon Storage‡	• Areas with Depleted Oxygen*	• Nitrate in Farmland Streams and Groundwater* • Phosphorus in Farmland Streams* • Soil Organic Matter*
Chemical Contamination	• Chemical Contamination*	• Contamination in Bottom Sediments*	• Pesticides in Farmland Streams and Groundwater*
Physical	• Change In Stream Flows‡	• Coastal Erosion • Sea Surface Temperature*	• Potential Soil Erosion • Soil Salinity • Stream Habitat Quality†
BIOLOGICAL COMPONENTS			
Plants and Animals	• At-Risk Native Species* • Established Non-native Species‡	• At-Risk Native Marine Species • Established Non-native Species in Major Estuaries* • Unusual Marine Mortalities	• Status of Animal Species in Farmland Areas • Established Non-native Plant Cover in the Farmland Landscape†
Communities	• Native Species Composition*	• Harmful Algal Events* • Condition of Bottom-Dwelling Animals	• Soil Biological Condition
Ecological Productivity	• Plant Growth Index*	• Chlorophyll Concentrations*	
GOODS AND SERVICES			
Food, Fiber, and Water	• Production of Food and Fiber and Water Withdrawals	• Commercial Fish and Shellfish Landings • Status of Commercially Important Fish Stocks* • Selected Contaminants in Fish and Shellfish	• Major Crop Yields • Agricultural Inputs and Outputs* • Monetary Value of Agricultural Production
Recreation and Other Services	• Outdoor Recreation • Natural Ecosystem Services*	• Recreational Water Quality	• Recreation in Farmland Areas

** Indicator refined since the 2002 State of the Nation's Ecosystems Report (original metric or metrics retained)*
† Indicator redesigned since the 2002 State of the Nation's Ecosystems Report
‡ New indicator since the 2002 State of the Nation's Ecosystems Report

	Forests	Fresh Waters	Grasslands and Shrublands	Urban and Suburban Landscapes
	• Forest Area and Ownership* • Forest Types* • Forest Management Categories*	• Extent of Freshwater Ecosystems* • Altered Freshwater Ecosystems*	• Area of Grasslands and Shrublands* • Land Use in Grasslands and Shrublands	• Area and Composition of the Urban and Suburban Landscape* • Total Impervious Area
	• Pattern of Forest Landscapes†	• In-Stream Connectivity‡	• Pattern of Grassland and Shrubland Landscapes†	• Streambank Vegetation • Housing Density Changes in Low-Density Suburban and Rural Areas† • "Natural" Lands in the Urban and Suburban Landscape†
	• Nitrate in Forest Streams* • Carbon Storage*	• Phosphorus in Lakes, Reservoirs and Large Rivers*	• Nitrate in Grassland and Shrubland Groundwater • Carbon Storage	• Nitrate in Urban and Suburban Streams* • Phosphorus in Urban and Suburban Streams*
		• Freshwater Acidity‡		• Urban and Suburban Air Quality* • Chemical Contamination*
		• Water Clarity • Stream Habitat Quality†	• Number and Duration of Dry Periods in Grassland and Shrubland Streams and Rivers* • Depth to Shallow Groundwater	• Urban Heat Island
	• At-Risk Native Forest Species* • Established Non-native Plant Cover in Forests	• At-Risk Native Freshwater Species* • Established Non-native Freshwater Species* • Animal Deaths and Deformities	• At-Risk Native Grassland and Shrubland Species* • Established Non-native Grassland and Shrubland Plant Cover* • Population Trends in Invasive and Non-invasive Birds	• Species Status • Disruptive Species
	• Forest Age* • Forest Disturbance: Fire, Insects, and Disease* • Fire Frequency • Forest Community Types with Significantly Reduced Area	• Status of Freshwater Animal Communities* • At-Risk Freshwater Plant Communities*	• Fire Frequency • Riparian Condition	• Status of Animal Communities in Urban and Suburban Streams
	• Timber Harvest* • Timber Growth and Harvest*	• Water Withdrawals • Groundwater Levels • Waterborne Human Disease Outbreaks	• Cattle Grazing	
	• Recreation in Forests	• Freshwater Recreational Activities	• Recreation on Grasslands and Shrublands	• Publicly Accessible Open Space per Resident • Natural Ecosystem Services*

What the Indicators Tell Us

Each of the indicators in *The State of the Nation's Ecosystems 2008* is important, as each contributes to a comprehensive picture of a specific ecosystem or the nation as a whole. However, this *Highlights* report focuses on a subset of the indicators that are relevant across multiple ecosystem types. These indicators were selected because they represent important features of the nation as a whole (the core national indicators) or because they report on features that are critical to more than one ecosystem (for example, nitrate in streams is important to farmlands, forests, and urban and suburban landscapes; fire is important to forests and grasslands and shrublands; and large-scale mortalities are important to coastal and freshwater ecosystems).

A Varied and Changing Landscape

America's ecosystems are vast and immensely varied, ranging from vibrant kelp forests to wide grassy plains, from Arctic tundra to subtropical cypress swamps. Grasslands, shrublands, and forests together cover much of the landscape of the lower 48 states, but there are many regional patterns of the mix of ecosystem types (see Figure 2). Croplands—the main component of farmland ecosystems—make up much of the remaining area, followed by freshwater and coastal wetlands and ponds that dot the landscape. While accounting for no more than a few percent of total area, developed land is not only found in major urban centers but is also scattered across much of the remaining landscape. Alaska, which is about one-quarter the size of the lower 48 states, is mostly covered by forests, grasslands, and shrublands, including large expanses of tundra.

In the lower 48 states there are

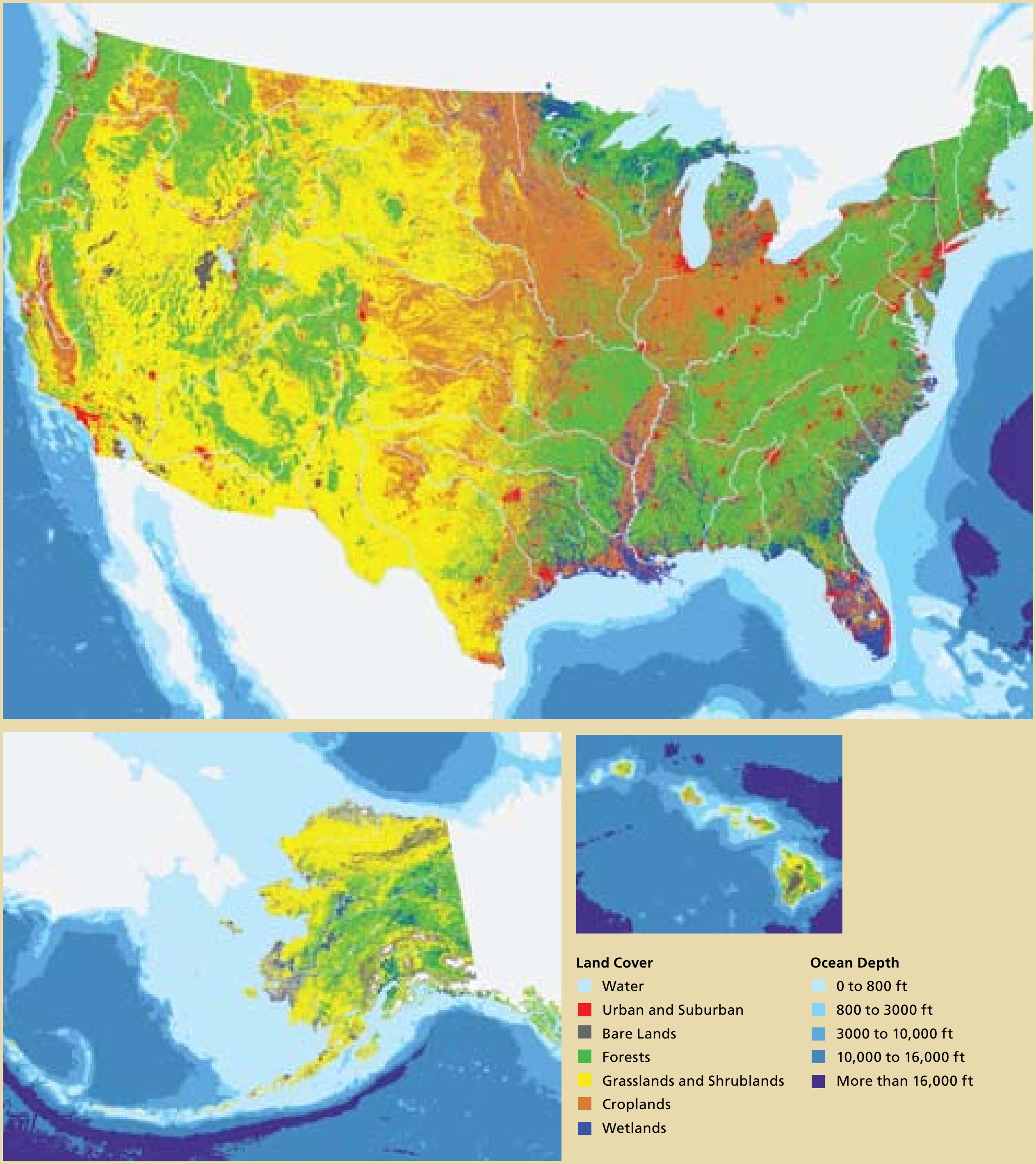
- 694 million acres of grasslands and shrublands
- 621 million acres of forests
- 400 million acres of croplands
- 96 million acres of freshwater wetlands
- 45 million acres of urban and suburban landscapes
- 6 million acres of freshwater ponds
- 5 million acres of coastal wetlands on the Gulf and Atlantic Coast

In Alaska there are

- 205 million acres of grassland and shrubland (including 135 million acres of tundra)
- 127 million acres of forests

[Sources: USDA Forest Service (forests), USDA Economic Research Service (croplands), Multi-Resolution Land Characterization (MRLC) Consortium, and ESRI (roadmap used in analysis of urban and suburban landscapes); analysis by the U.S. Environmental Protection Agency and the U.S. Forest Service (grasslands and shrublands, urban and suburban landscapes), and the U.S. Fish and Wildlife Service National Wetlands Inventory (wetlands and ponds).]

FIGURE 2 U.S. Land Cover and Ocean Depth



This image uses satellite remote sensing information to show the distribution of ecosystem types described in The State of the Nation's Ecosystems 2008. It covers forests, croplands (including pastures and haylands), grasslands and shrublands, urban and suburban landscapes, most wetlands, and rivers with flows that exceed 1000 cubic feet per second. The map also includes information on the depth of coastal waters, which will be complemented by data on the extent of brackish waters when such data become available. Data source: Multi-Resolution Land Characterization (MRLC) Consortium and ESRI (road map); analysis done by analysts with the U.S. Forest Service and the U.S. EPA; Alaska: USGS; Hawaii: NOAA; bathymetry data: NOAA; analysis by USGS EROS data center

The U.S. landscape has changed substantially in the last half-century. There have been increases in the area of urban development and the area of ponds and declines in the area of croplands and freshwater and coastal wetlands. Forest area has not changed significantly nationwide.

- Between 1945 and 2002, the area of "developed land" (a proxy for the area of urban and suburban landscapes) increased from 15 million acres to 60 million acres. (Source: U.S. Census Bureau.)
- Cropland area has declined by 12% nationwide since 1982; however, the cropland acreage in the two river basins with the greatest agricultural acreage—the Missouri and the Souris–Red Rainy/Upper Mississippi—has remained relatively stable. (Sources: USDA Natural Resources Conservation Service, National Resources Inventory, and USDA Economic Research Service.)
- Since 1953, forest area for the nation as a whole has changed by less than 1%; however, forest area has increased in the North and decreased in the South and Pacific Coast. (Source: USDA Forest Service.)
- Since 1955, the freshwater wetland area has declined by 9%. Over the same period, the area of ponds has more than doubled. (Source: U.S. Fish and Wildlife Service.)
- From the mid-1950s to 2004, more than 400,000 acres of vegetated wetlands on the Gulf and Atlantic coasts were lost, a decline of about 9%. (Source: U.S. Fish and Wildlife Service.)

As land is converted from one ecosystem type to another, the *pattern* of ecosystems in the landscape often changes along with extent—suburban developments may be built in areas that were formerly forests or grasslands, or abandoned farms may become forest again. Changes in the proximity of ecosystems to one another and the way they are intermingled can affect how these ecosystems function and the good and services they provide. We describe the pattern of small parcels of "natural" land based on the mix of land cover ("natural," cropland, and development) in the 240 acres surrounding each parcel. Highly managed landscapes—be they croplands or developed areas—break up expanses of "natural" lands.

- About 68% of the land cover of the lower 48 states is "natural" (forest, grasslands, shrublands, wetlands, lakes, or coastal waters). (Source: Multi-Resolution Land Characterization Consortium and ESRI.)
- Twenty-three percent of the "natural" land cover is described as "core natural" (that is, it has only other "natural" land in the 240 acres surrounding it). The Rocky Mountain region has the highest percentage of "core natural" parcels, and the Midwest has the lowest. (Source: Multi-Resolution Land Characterization Consortium and ESRI).
- Patches of "core natural" parcels were most often 10–100 square miles in size, with 11% of these patches at least 1000 square miles—the Rocky Mountain region had the highest percentage of these large patches. (Source: Multi-Resolution Land Characterization Consortium and ESRI.)

Conversion of land from rural to urban or suburban is generally permanent, and this conversion profoundly changes the benefits and services the land provides. Development in the lower-density areas of the urban–suburban landscape and in rural areas can have more ecological consequences than development in areas with higher preexisting housing densities because it can deforest and fragment habitat, interfere with the movement of animals, and reduce stream quality, and it often leads to further development.

- The Eastern United States has a larger proportion of its total area (4% to 5%) in urban and suburban landscapes than other regions (0.5% to 3%). (Source: Multi-Resolution Land Characterization Consortium and ESRI.)
- Between 1990 and 2000, most new housing development in rural and suburban areas took place in areas with preexisting housing densities of between 1 and 40 housing units per acre. More housing units were built in the East than in the West. [Source: U.S. Census Bureau, analyzed by D.M. Theobald (Colorado State University).]

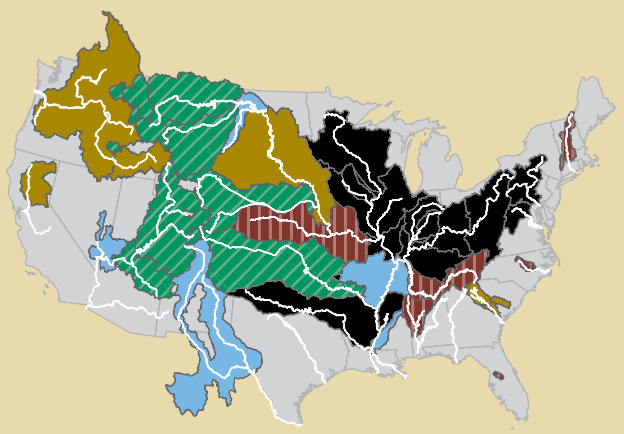
Alterations of "natural" stream banks or coastal shorelines can allow pollutants to enter streams more easily, reduce shading and thus increase water temperature, and reduce habitat quality for species that need both in-stream and shoreline habitat. "Armored" coastlines can help protect against erosion and storm damage but may isolate coastal wetlands from tidal influence and may ultimately result in unexpected erosion, either locally or in adjacent areas.

- Six percent of the nation's coastline is armored with bulkheads or riprap, while 20% of the nation's stream and river banks are in urban or agricultural land use. (Sources: National Oceanic and Atmospheric Administration, Multi-Resolution Land Characterization Consortium and ESRI.)

Nutrients—on the Land and in the Water

Nitrogen is a vital nutrient for plants and animals, but one that can change the makeup of forests, contaminate groundwater wells, or trigger the growth of algae in coastal waters if present in excess. Nitrogen reaches fresh waters primarily through runoff from fertilized farms, lawns, and gardens, as wastewater treatment discharge, and in precipitation (from fossil fuel combustion). Elevated nitrogen in untreated drinking water can cause health problems, while nitrogen in streams or groundwater can eventually reach the coast as well, where it can contribute to water quality problems (see "Oxygen—the Lifeblood of Our Coasts," below). Nitrogen (and sulfate) deposited in rain or snow ("acid rain") can also harm lakes and streams by raising their acidity.

FIGURE 3 Delivery of Total Nitrogen to Streams and Rivers from Major Watersheds (2001–2005)



Data source: U.S. Geological Survey's National Stream Quality Accounting Network (NASQAN), National Water Quality Assessment (NAWQA), and Federal–State Cooperative Program. Coverage: areas of the lower 48 states with major river basins and available data. Technical details: The delivery of nitrogen to streams and rivers is averaged across the area of the watershed and reported as pounds of nitrogen per square mile.

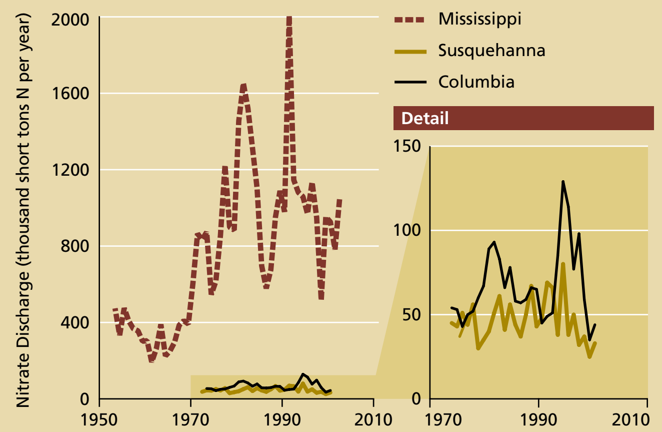
- In more than half of the areas monitored (see Figure 3), more than 600 pounds per square mile of nitrogen are delivered each year to streams and rivers. (Source: USGS, National Water Quality Assessment and National Stream Quality Accounting Network.)
- Streams and groundwater in farmland areas have higher concentrations of nitrate—a common form of nitrogen—than streams in forested or urban and suburban areas, most likely from nitrogen fertilizer applied by farmers. Between 1992 and 2003, 20% of groundwater wells had nitrate concentrations that exceeded the federal drinking water standard, and between 1992 and 2001, 13% of streams in farmland areas had nitrate concentrations that exceeded the standard. (Source: USGS, National Water Quality Assessment.)
- Three rivers—the Mississippi, the Columbia, and the Susquehanna—together discharge approximately 1 million tons of nitrogen in the form of nitrate per year to coastal waters, with more than 90% of that nitrogen carried by the Mississippi (see Figure 4). (Source: USGS, National Water Quality Assessment and National Stream Quality Accounting Network.)
- Discharge of nitrate from the Mississippi River rose substantially from the 1950s to the 1980s, but there has been no clear upward or downward trend since 1983; for the Susquehanna and Columbia Rivers, there has been no clear trend since the 1970s (see Figure 4). (Source: USGS, National Water Quality Assessment and National Stream Quality Accounting Network.)

- Just over 2% of U.S. wadeable streams are considered "highly acidic," with almost twice that percentage in parts of the Appalachians. (Source: U.S. Environmental Protection Agency, Wadeable Streams Assessment.)

Elevated levels of phosphorus in rivers, streams, and lakes can lead to the excessive growth of algae and other aquatic plants, which can be unsightly, interfere with recreation, clog industrial and municipal water intakes, and harm fish and other aquatic animals by causing dissolved oxygen levels to drop. The EPA has recommended 0.1 parts per million (ppm) as a goal for preventing excess algae growth in streams not draining directly into a lake or other impoundment.

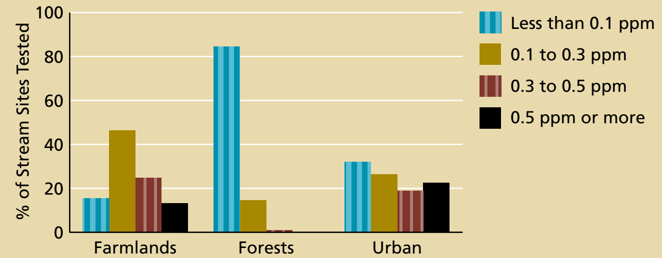
- Between 1992 and 2001, streams in urban areas and farmlands had higher phosphorus concentrations than streams in forested areas (see Figure 5). (Source: USGS, National Water Quality Assessment.)
- Half of major rivers sampled for phosphorus had concentrations of at least 100 ppb. (Source: USGS, National Water Quality Assessment and National Stream Quality Accounting Network.)

FIGURE 4 Nitrate Input to Coastal Waters by Major U.S. Rivers



Data Source: U.S. Geological Survey's National Stream Quality Accounting Network (NASQAN), National Water Quality Assessment (NAWQA), and Federal–State Cooperative Program. Coverage: major rivers with available data.

FIGURE 5 Ecosystem Comparison: Total Phosphorus in Streams, 1992–2001



Data source: U.S. Geological Survey, National Water Quality Assessment Program. Coverage: 51 major river basins across 50 states. Technical details: data are from sites that are primarily farmlands, forests or urban and suburban landscapes. Each sampling area was sampled intensively for approximately 2 years during 1992–2001.

Oxygen—the Lifeblood of Coastal Waters

Nitrogen delivered to estuaries and other coastal areas can promote excessive growth of algae whose decay removes oxygen (phosphorus can cause the same phenomenon in rivers and lakes). Low oxygen levels can cause stress or death to fish, shellfish, and marine mammals. Prolonged periods of low oxygen levels can affect recreational and commercial fisheries and harm plant and animal communities.

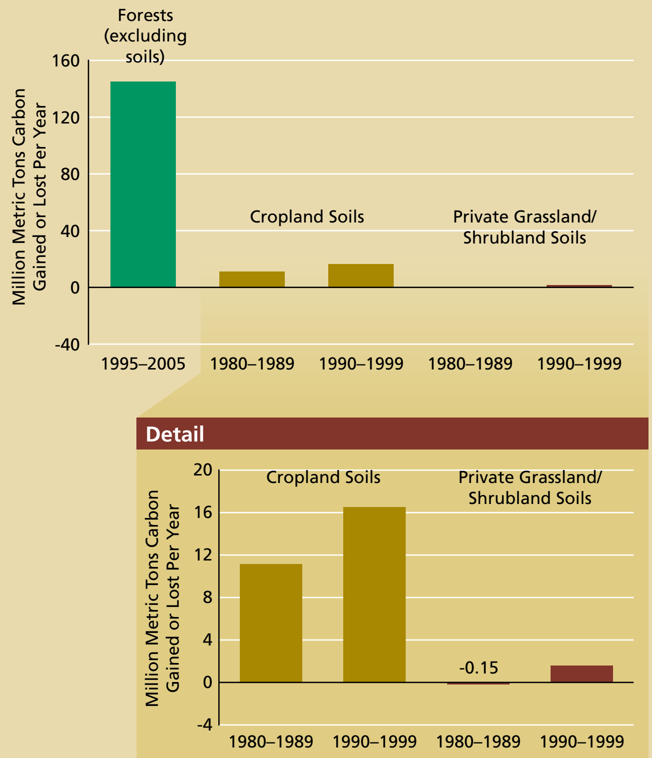
- The area of the Gulf of Mexico with low oxygen levels (measured in July) has more than doubled over the past 22 years, from about 3800 square miles in 1985 to about 7900 square miles in 2007 (press reports indicate that in 2008 the zone will be yet larger). (Source: N. N. Rabalais and R. E. Turner.)
- There has been no clear upward or downward trend in the area of the hypoxic zone in Chesapeake Bay since 1985, but during that time the hypoxic zone has covered between 10% and 25% of the area of the bay. (Source: Chesapeake Bay Program.)

Carbon—on Land, in the Soil, and in the Air

Carbon in the form of organic matter is a key element of productive ecosystems. When stored ("sequestered") in ecological reservoirs such as soils and in durable plant materials like tree trunks and large roots, carbon serves to offset emissions of carbon dioxide and methane to the atmosphere, where they trap solar radiation and contribute to the greenhouse effect. National-scale estimates

FIGURE 6 Carbon Gained or Lost, by Ecosystem Type over Time

Partial Indicator Data: Forests (above- and below-ground biomass only, excluding soil), croplands and grasslands/ shrublands (soil carbon only, private lands only)



Data source: Natural Resource Ecology Laboratory (NREL), Colorado State University; USDA Forest Service. Coverage: lower 48 states (all data); cropland and grassland–shrubland soils on private lands only (top 8 inches; NREL data); above-ground forest carbon, both live and dead (Forest Service). Unit conversion: 1 metric ton = 1.10 U.S. tons.

of carbon storage are unavailable for many terrestrial and aquatic ecosystem types, so it is not possible to provide a complete picture of carbon sequestration in the United States; however, where national-scale estimates have been made, carbon levels have increased.

- From 1995 to 2005, forests gained nearly 150 million metric tons annually in above- and below-ground plant materials; information on forest soils is not widely available. (Source: USDA Forest Service.)
- In the 1990s, cropland soils added 16.5 million metric tons of carbon per year, and private grasslands and shrubland soils gained 1.6 million metric tons per year (see Figure 6). (Source: Natural Resource Ecology Laboratory, Colorado State University.)

A strong scientific consensus exists that additional increases in atmospheric greenhouse gas concentrations are very likely to alter climate patterns and have significant effects on people and ecosystems worldwide. Positive effects, such as longer growing seasons, may be offset by negative effects, such as water shortages.

- In 2006, the atmospheric concentration of carbon dioxide (381 parts per million) was 36% greater than the average concentration during pre-industrial times and has increased by 20% since the 1950s. [Source: Multiple data sources used by Working Group I of the Intergovernmental Panel on Climate Change (IPCC), 2007.]
- The atmospheric concentration of methane in 2005 (1805 parts per billion) was 160% higher than the average preindustrial concentration and has increased by 55% since the 1950s. [Source: Multiple data sources used by Working Group I of the Intergovernmental Panel on Climate Change (IPCC), 2007.]

Chemical Contamination—in Water, Sediments, Air, and Fish

Modern society produces a host of useful compounds, many of which are now present in the air, water, sediment, soil, and animal and human tissues. In sufficient quantities, these chemical contaminants can affect human health, restrict people's use of ecosystems, and harm plants and animals. Contaminants in drinking water affect human health, contaminants in fish trigger consumption advisories, and many wildlife species have been harmed by biological concentration of pesticides (as with bald eagles and DDT).

(Data below are from U.S. Geological Survey, National Water Quality Assessment Program and U.S. Environmental Protection Agency, National Coastal Assessment Program.)

At least one contaminant was detected (see Figure 7) in

- Seventy-five percent of the groundwater wells tested
- Virtually all the streams and stream sediments tested
- About 80% of the estuarine sediments tested
- About 80% of the freshwater fish tested
- Nearly all of the saltwater fish tested

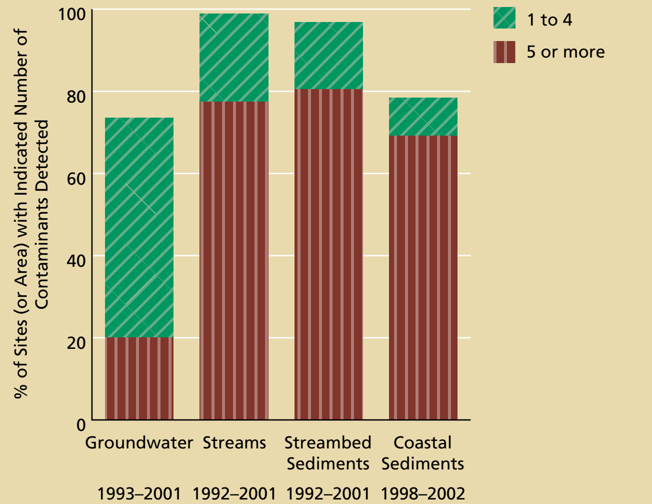
At least one contaminant was detected at levels above benchmarks set to protect aquatic life in more than 50% of the

- Stream water samples
- Stream sediment samples
- Estuarine sediment samples
- Freshwater fish tissue samples

At least one contaminant was detected at levels above benchmarks to protect human health in

- One-third of the groundwater samples
- One-third of the saltwater fish samples
- One-fifth of stream water samples

FIGURE 7 Contaminants Detected: Groundwater, Streams, and Sediments



Data source: U.S. Geological Survey National Water Quality Assessment (NAWQA) Program. U.S. Environmental Protection Agency National Coastal Assessment Program (NCA). Coverage: 51 major river basins and 54 major aquifers across the nation (NAWQA data); all coastal states (in Alaska, south-central region only) including Puerto Rico (NCA data). Technical details: 85 contaminants sampled at 186 stream sites (1992–2001); 104 contaminants sampled at 957 streambed sites (1992–2001); 194 contaminants sampled in 2282 groundwater wells (1993–2002); 81 contaminants sampled in 2146 coastal sediment sites (1998–2002) reported as "% of area." Detections of naturally occurring compounds (nitrate, ammonia, metals, radionuclides) are excluded.

Certain contaminants are of particular interest or concern in specific ecosystems. In farmlands, pesticides may affect water quality; in urban and suburban landscapes, outdoor air quality is of particular concern because of its effects on human health, vegetation, animals, and the built environment.

- In farmlands, about 57% of streams had at least one pesticide at concentrations exceeding benchmarks for the protection of aquatic life; about 16% had at least one pesticide at levels exceeding benchmarks for protection of human health. (Source: U.S. Geological Survey, National Water Quality Assessment Program.)
- In 2005, ozone levels were above the level set for the national air quality standard at 30% of urban and suburban monitoring stations on four or more days; 61% had high levels on at least one day. (Source: U.S. Environmental Protection Agency.)
- In 2005, 28% of urban sites nationwide reported fine particulate matter at concentrations of 15 micrograms per cubic meter or above—a concentration comparable to EPA's national annual standard. (Source: U.S. Environmental Protection Agency.)

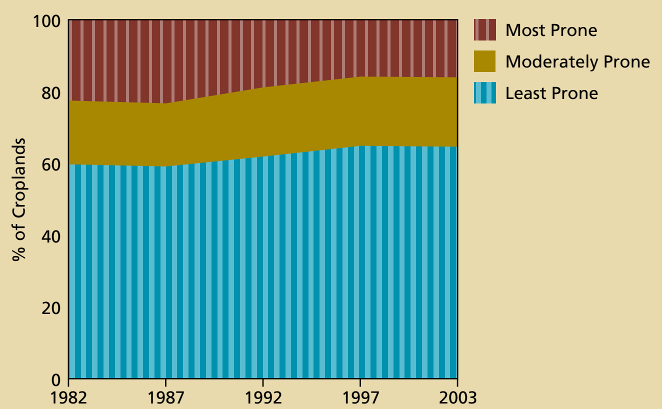
Amount, Timing, and Availability of Water

All ecosystems depend on water to support life. The amount available and the timing of its availability help shape ecosystems physically (such as through erosion), influence what species can live in an area, and determine how much water people can withdraw from ecosystems. While precipitation and resulting stream flows vary naturally over both years and decades (for example, the drought of the 1930s), there is substantial scientific evidence that a warming climate will be accompanied by significant shifts in the timing and amount of rainfall, with some areas becoming drier than they were historically, and others wetter. In addition, whether precipitation comes as rain or snow will have a major effect on stream flows, as some areas are reliant upon snowmelt for large parts of the year.

- Many U.S. streams have shown a change of more than 30% in the volume and variability of stream flow compared to a baseline period in the 1940s and 50s. Change has included both increases and decreases in high flow volume, low flow volume, and variability of volume. (Source: U.S. Geological Survey.)
- Nationwide, a growing proportion of streams have low flows with a substantially higher low flow rate than during the baseline period, and grassland–shrubland streams show fewer and shorter zero-flow incidents. (Source: U.S. Geological Survey.)
- A growing proportion of streams have shown a decrease in both high flow rates and in the variability of flow compared to the 1941–1960 baseline period. (Source: U.S. Geological Survey.)

These results do not yet provide evidence for major precipitation shifts, but this indicator—especially at the regional level—will be crucial to understanding how climate is affecting ecosystems.

FIGURE 8 Wind Erosion Potential



Data source: USDA Natural Resources Conservation Service. Coverage: lower 48 states; data cover cropland and Conservation Reserve Program lands, but not pasture. Technical details: data are based on an index that combines information on soil characteristics, topography, and management activities such as tillage practices and whether crop residue is left on the field or not.

Erosion and Sediments—Rivers and Streams, Farmlands and Coasts

Erosion in agricultural areas reduces soil quality and degrades water and habitat quality, while erosion in coastal areas can threaten developed areas, result in habitat loss or alteration, redistribute nutrients, and affect coastal recreation. While data are not adequate for reporting on coastal erosion, data are available on potential soil erosion in farmlands (erosion itself is not measured—this indicator measures soil conditions that promote erosion).

- From 1982 to 2003, the proportion of U.S. croplands with the greatest potential for wind erosion decreased by nearly a third (see Figure 8).
- A similar decline was seen for cropland soils with the greatest potential for water erosion.
- The potential for wind erosion tends to be greater in the West, while the potential for water erosion is greater in the East. (Source: USDA Natural Resources Conservation Service.)

Change in the condition of streambed sediments—ranging from fine sediment to pebbles and cobbles—is a measure of alteration of stream features such as the amount and velocity of water and the amount of eroded sediment it receives. Degradation of sediment quality compared to reference streams implies a reduction in the quality of habitat for fish, other animals, and plants. For example, excess sediment from agricultural erosion or after wildfires can smother the eggs of fish.

- In fresh waters, about 25% of stream-miles in the lower 48 states have “degraded” sediments and about half have “natural” sediments. Sediments are in moderate condition for 20% of stream-miles. (Source: U.S. Environmental Protection Agency, Wadeable Streams Assessment.)

Changing Temperature—Oceans and Cities

In coastal ecosystems, water temperature directly affects the type of algae, seagrass, marsh plants, mangroves, fish, birds, mammals, and other plants and animals that live in a particular region. In addition, increases in temperature are thought to be associated with the degradation of coral reefs (bleaching) and may increase the frequency or extent of blooms of harmful algae.

- From 1985 to 2006, sea surface temperature increased significantly in U.S. coastal waters (within 200 miles of the coast) in three regions—Gulf of Alaska, Gulf of Mexico, and South Atlantic—and showed no observable trend for the North and Mid-Atlantic, Southern California, Bering Sea, Pacific Northwest or Hawaii regions. (Source: National Oceanic and Atmospheric Administration, National Aeronautics and Space Administration.)

Air temperatures in urban areas are often higher than in surrounding rural areas— the "urban heat island" effect. Heat waves are often responsible for the loss of human life, and they are considered likely to increase in intensity, duration, and geographical range as climate warms. The heat island effect may change the community of plants and animals that live in an area (including pathogens) and accelerate the formation of ground-level ozone and other pollutants that adversely affect human health. Some cities are taking steps, such as encouraging "green roofs," designed to keep cities cooler. Unfortunately, data are not adequate for national reporting on the urban heat island effect.

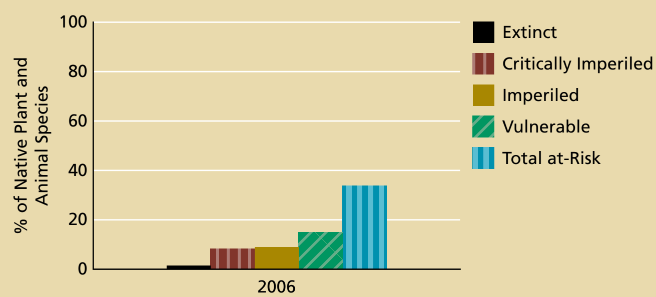
At-Risk Plants, Animals, and Communities

Ecosystems are defined in part by individual species and communities (groups of plants and animals that tend to occur in similar environmental conditions). These species and communities provide people with food, fiber, and a vast array of recreational opportunities. Species can also provide genetic materials that may have various industrial, agricultural, and medicinal uses—for example, the Pacific yew tree is the source of paclitaxel, a compound used in cancer treatment.

While some species are naturally rare, many have experienced historical or more recent declines and as a result many species and plant and animal communities are at risk of extinction (species) or elimination (communities). The loss of native species changes community composition and may affect the ability of the ecosystem to provide benefits or to respond to stresses, such as changing climate, particularly if there are few species with similar ecological roles.

FIGURE 9 At-Risk Native Species, by Risk Category (2006)

Partial Indicator Data: Native Terrestrial and Freshwater Plant and Animal Species

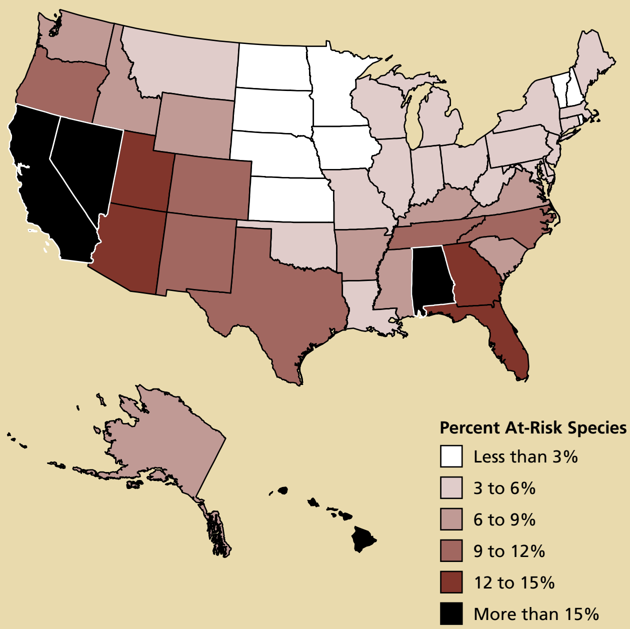


Data source: NatureServe and its Natural Heritage member programs. Coverage: all 50 states. Technical details: The degree of risk for any particular species varies considerably, from those species that are relatively secure, to those that are in imminent danger of extinction. The data cover many of the best-known groups of terrestrial and freshwater native plants and animals, totaling about 22,600 native species. Species are assessed based on such factors as the number and condition of individuals and populations, population trends, the area occupied by the species, and known threats. In all cases, a wide variety of factors contribute to overall ratings.

- In 2006, one-third of native plant and animal species (excluding marine species) were at risk of extinction (see Figure 9), with the highest incidence of at-risk species in Hawaii (81%), California (29%) and Nevada (16%). In contrast, the Midwest and Northeast/Mid-Atlantic had the lowest percentages—generally below 6% (see Figure 10).
- The percentage of at-risk native animals is higher in fresh waters (37%) than in forests (19%) or grasslands and shrublands (18%).

FIGURE 10 At-Risk Native Species, by State (2006)

Partial Indicator Data: Native Terrestrial and Freshwater Plant and Animal Species



Data source: NatureServe and its Natural Heritage member programs. Coverage: all 50 states. Note that state data are not available for the following: the Giant Silkworm, Royal Moths, Sphinx Moths and Grasshopper.

- Nationally, about 28% of native vertebrate animal species at risk have declining populations, 23% have stable populations, and 1% have increasing populations. Population trends for the remaining native vertebrate animal species (48%) were unknown.
- In fresh waters, forests, and grasslands and shrublands, a large majority of native animal species with known population trends have populations that are either stable or declining, and fewer than 3% have populations that are increasing. (Source: NatureServe and its Natural Heritage member programs.)

Many freshwater plant communities are also at risk of elimination. In 2006

- Sixty-two percent of wetland and river- and stream-bank communities were at risk of elimination.
- In all states but West Virginia, Maine, New Hampshire, Rhode Island, and Vermont more than 20% of freshwater plant communities were at risk of elimination; in nine states, including several in the Southeast, more than 60% of freshwater communities are at risk. (Source: NatureServe and its Natural Heritage member programs.)

Non-native Species—Changing the Native Landscape

Established non-native species may act as predators or parasites of native species, cause diseases, compete for food or habitat, or alter habitat. They may also provide ecosystem services such as soil stabilization or forage for grazing animals. Significant public and private funds are spent to control the most troublesome non-native species—often called invasive species—such as zebra mussels, cheatgrass, English ivy, and melaleuca.

While understanding the spread of these species is crucial to understanding ecological condition, data are currently not adequate to report on established non-native species on a national scale, with the exception of non-native fish.

- Fifty-eight percent of watersheds have more than 10 established non-native fish species. Only two watersheds in the lower 48 states have no established non-native fish species. Watersheds in the central United States generally have the fewest non-native fish species (see Figure 11).

Condition of Biological Communities

Assessing the condition of a species is relatively straightforward—one measures population size and trends, area occupied (range), status of threats, and the like. Assessing the status of biological communities is more difficult. In fact, at a national scale, well-accepted methods (and data) are available for assessing communities only in estuaries and wadeable streams, using measures of the condition of bottom-dwelling animals. The condition of insects, worms, mollusks, and crustaceans in bottom sediments is of particular importance because these animals directly reflect changes in water quality and other disturbances and are a key part of the food chain. Changes in biological condition reflect the influence of contaminants, oxygen levels, physical changes in habitats (such as from trawl fishing in coastal areas or sediment deposition in streams), shifts in temperature or salinity, and the amount and timing of stream flows.

- In 1999–2002, from 60% to 90% of the estuarine area on the Atlantic and Pacific coasts had bottom-dwelling animals in "natural" condition; about one-third of the estuary area in the Gulf of Mexico and Puerto Rico had bottom-dwelling animals in "natural" condition. "Degraded" communities covered 44% of the estuarine area in the Gulf of Mexico. (Source: U.S. Environmental Protection Agency, National Coastal Assessment.)
- Between 2000 and 2004, bottom-dwelling animals were in "natural" condition in 28% of wadeable streams in the lower 48 states; 42% of streams had bottom-dwelling animals that were in "degraded" condition; and 25% of wadeable streams had bottom-dwelling animals in "moderate" condition. The West had a higher proportion of stream-miles with "natural" bottom-dwelling communities than the Eastern Highlands and the Plains and Lowlands (see Figure 12). (Source: U.S. Environmental Protection Agency, Wadeable Streams Assessment.)

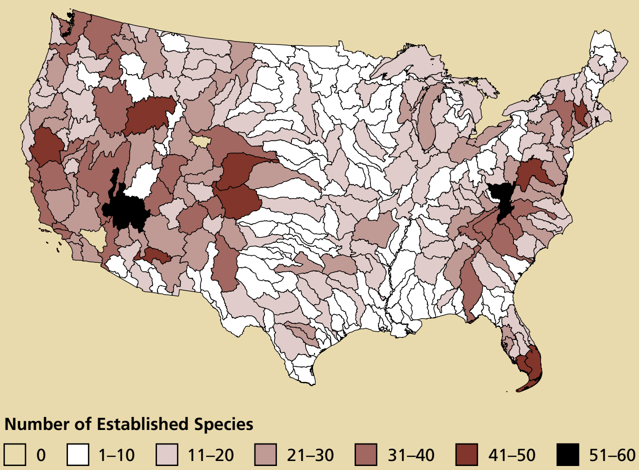
Disturbance and Mortality—Forests, Oceans, and Fresh Waters

Periodic disturbances such as fire, floods, and insect outbreaks are "normal" in many ecosystems. In other ecosystems, "die-offs" of birds, whales, dolphins, or other species are believed to be a signal of ecosystem disruption. Assessing whether these disturbances are more or less frequent compared to long-term trends is a useful part of determining a system's condition.

While fires and insects are a natural part of forest life, the introduction of non-native pests such as gypsy moths or severe fire events following

FIGURE 11 Established Non-native Species, 2007

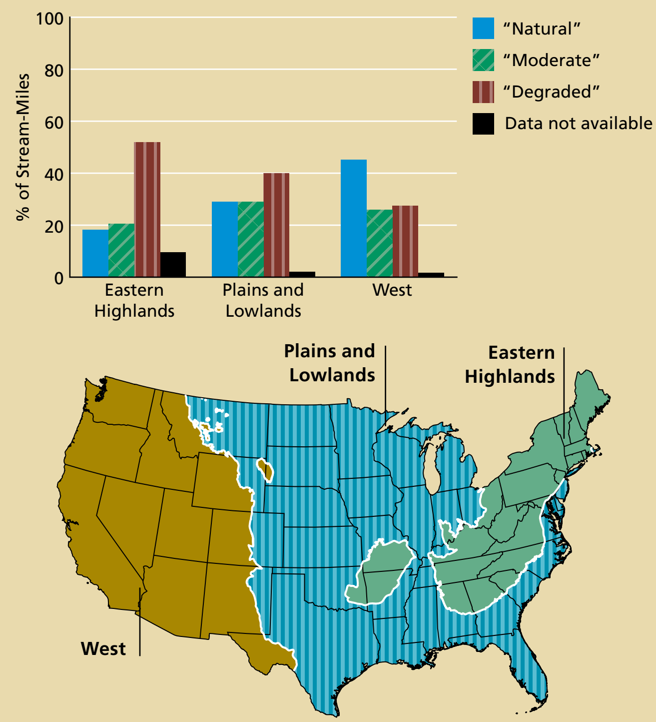
Partial Indicator: Fish Species in U.S. Watersheds



Data source: U.S. Geological Survey. Coverage: lower 48 states.

FIGURE 12 Biological Community Integrity, by Region, 2000–2004

Partial Indicator Data: Bottom-Dwelling Animals in Wadeable Streams



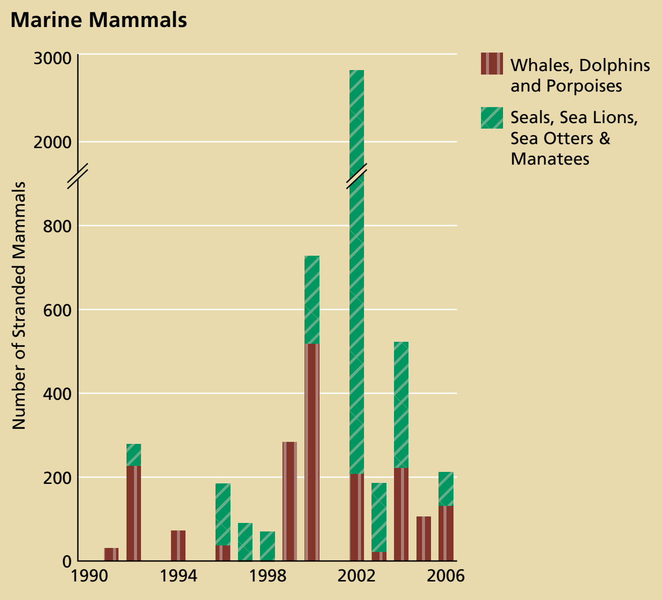
Data source: U.S. EPA, Wadeable Streams Assessment (2006). Coverage: lower 48 states. Technical details: Tests of biological integrity assess the number of different species, the number and condition of individuals, and food chain interactions. The regional definitions presented here are based on the Omernik's Level III ecoregions (see http://nationalatlas.gov/mld/ecoomrp.html). These regions are consistent with those used by the U.S. Environmental Protection Agency, Wadeable Streams Assessment.

long periods of fire suppression can devastate large areas of forest. Large-scale fires can also increase erosion and sedimentation in streams and increase the likelihood of invasion by non-native species.

- Although there has been a significant decline in the acreage of forests and grasslands and shrublands burned since 1916, in recent years (1979–2006) this trend has reversed, with a total of 9.8 million acres burned in 2006. (Source: USDA Forest Service and National Interagency Fire Center.)
- Since 1997, the number of acres of tree mortality due to insect damage has also increased. (Source: USDA Forest Service.)

In coastal waters, harmful algal events can sicken people and cause mass mortalities of fish and wildlife. Increased nutrient loads, some aquaculture practices, ballast water discharge from ships, and overfishing may contribute to the frequency and severity of such events. Further indicator development is required before it is possible to report fully on harmful algal events.

FIGURE 13 Unusual Marine Mortalities



Data source: National Marine Fisheries Service. Coverage: all U.S. waters.

Unusual marine mortalities may threaten sensitive marine populations and may indicate that stresses such as toxins, pollution, or changing weather are affecting marine ecosystems.

- Between 1990 and 2006, the number of whales, dolphins, porpoises, seals, sea lions, sea otters, and manatees dying each year in unusual marine mortality events fluctuated widely, from zero to several hundred animals, with one year (2002) having almost twenty times the average for other years (see Figure 13). Most of these mortality events are believed to have been caused by infectious disease or by toxins produced by algae. (Source: National Marine Fisheries Service.)

At present, data are not adequate for reporting on the number of animal deaths and deformities in fresh waters.

Ecosystem Productivity

The ability of plants to use energy from the sun to build plant matter drives and sustains nearly all life. Therefore, changes in plant growth can signal alterations in how an ecosystem is functioning and can be related to increases or decreases in yields of timber and food crops and possibly to changes in the numbers and types of species that live in the region. Altered productivity may result from changing climate, exposure to ground-level ozone, as well as from changes in land use or farm or forest management. In marine ecosystems, conversion of sunlight to plant material is measured as the concentration of chlorophyll (from algae and similar marine plants) in the water.

- Nationwide, the plant growth index—a measure of plant growth or productivity—has shown little annual variability over the 1982–2003 time period.
- Cropland and grassland areas showed slight increases in the plant growth index, while forest and shrubland areas showed no clear up or down trend.

- Compared to other regions, the Southeast and portions of the Midwest had the most land with increases in the plant growth index (see Figure 14). (Source: National Aeronautics and Space Administration.)
- Chlorophyll concentrations in coastal waters have increased in the Pacific Northwest, Southern California, and North Atlantic regions (1997–2006). (Source: National Oceanic and Atmospheric Administration, National Ocean Service; National Aeronautics and Space Administration.)

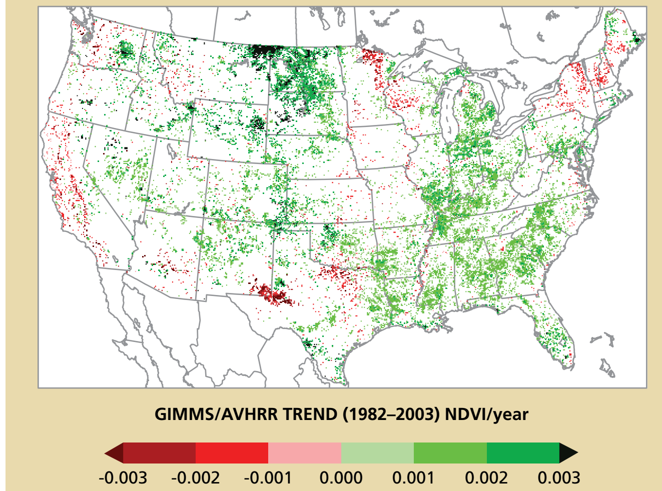
Food, Fiber, and Water Withdrawal—the Goods We Use

The United States relies heavily on domestic resources to meet its food, fiber, and water needs. We build homes with timber from U.S. forests; dine on fruits and vegetables from local farms as well as large-scale farming operations in distant states; eat meat from livestock grazed for part of the year on our grasslands and shrublands; and divert water from our rivers, lakes, and aquifers to drink, irrigate our crops, run our factories, and power our hydroelectric plants. Changes in the quantities of these extracted goods can affect both the economy and human well-being.

- Each year the United States harvests or withdraws
  - 4.6 million tons of fish and shellfish from coastal waters (commercial landings only, 2005)
  - 21.2 billion cubic feet of timber from forests (2005)
  - Agricultural products valued at $239 billion from farmlands (2005)
  - 126 trillion gallons of water from fresh waters (2000)

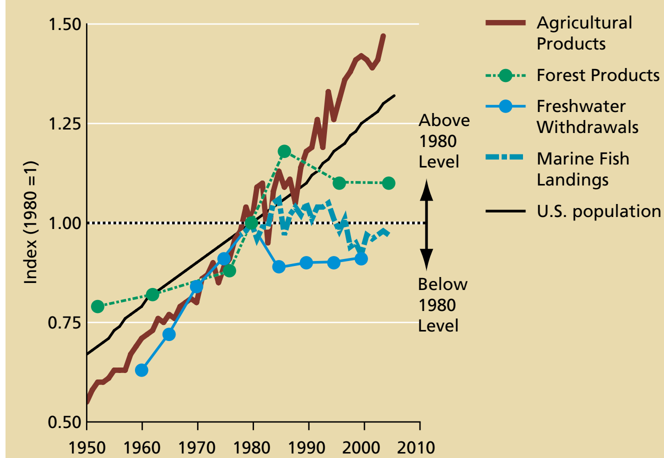
  (Sources: National Marine Fisheries Service, USDA Forest Service, USDA Economic Research Service, U.S. Geological Survey.)
- Nationally, the production of agricultural goods, the harvest of forest products, and our withdrawals of fresh water have all increased in the past half-century. However, only the production of agricultural products has grown at a rate exceeding population growth (see Figure 15). (Sources: USDA Economic Research Service, USDA Forest Service, U.S. Geological Survey, U.S. Census Bureau.)

FIGURE 14 Plant Growth Index Trend, 1982–2003



Data source: NASA [analysis by Terrestrial Observation and Prediction System (TOPS) / Ames Research Center, NASA]. Coverage: lower 48 states. Technical details: Data for 1982–2003 were analyzed to determine if the index value was increasing or decreasing. Green values represent an increase in index values over the period for a particular 5-mile-square pixel, and red values represent a decrease. White represents areas with no significant trend up or down.

FIGURE 15 Production of Food and Fiber, and Water Withdrawals: Entire United States



Data source: USDA Economic Research Service, USDA Forest Service, U.S. Geological Survey, National Marine Fisheries Service, U.S. Census Bureau. Coverage: all 50 states. Technical details: Agricultural products include livestock raised on grasslands and shrublands. Fish landings before 1978 do not include foreign landings and so are not reported.

The nation's efficiency at producing farm and forest products has also increased. Agricultural output has increased by approximately 170% since 1948, and the amount of inputs (energy, fertilizer, and so on) needed to produce each unit of farm output has changed; timber harvest has also increased.

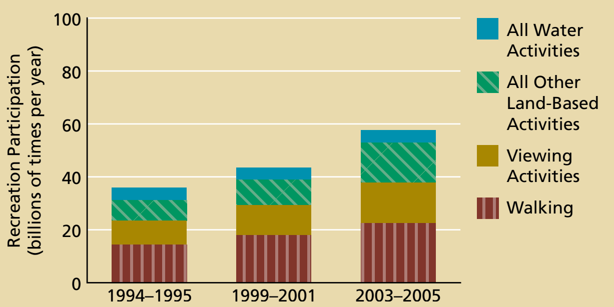
- The amount of land needed to produce each unit of agricultural output has dropped by 70% since 1948, and the amounts of purchased energy and durable goods like tractors has also declined (by 60% and 42%), accompanied by increases in pesticide and fertilizer use. Between 1948 and 2004, fertilizer inputs per unit output increased 46% and pesticide inputs doubled. (Source: USDA National Agricultural Statistics Service.)
- Yields per acre of five major crops—wheat, corn, soybeans, cotton, and hay—have increased since 1950, with corn yields alone increasing nearly fourfold. (Source: USDA National Agricultural Statistics Service.)
- While the area covered by forests in the United States has remained stable—dropping less than 1% over the past 50 years—over the same period harvest of forest products increased by 40%. Since 1952, timber growth on both public and private timberlands has increased. As of 2005, more than half of all U.S. timber was harvested from southern forests. Southern forests are predominantly privately owned (87%), are younger, more frequently harvested, and have a greater proportion of forested land in planted timberland (sometimes referred to as "plantations" or "tree farms"), compared to forest stands in the western United States. (Source: USDA Forest Service.)

In the past half-century, we have also obtained more goods from our freshwater and coastal ecosystems.

- Between 1960 and 2000, surface water and groundwater withdrawals combined increased by 46%. Municipal, rural and thermoelectric water uses increased during this period, while industrial withdrawals declined. (Source: U.S. Geological Survey.)
- Between 1950 and 2005, commercial fish and shellfish landings in the United States increased by almost 90%. Since 1990, Alaskan waters have accounted for the bulk of U.S. commercial landings. Alaska is the only region where landings have increased since 1978. Landings have decreased between 1978 and 2005 in the West Coast and Hawaii, the Gulf of Mexico, and the North, Mid-, and South Atlantic. From 1996 to 2005, with the exception of Alaskan and migratory stocks, a greater percentage of known fish stocks have increasing population trends than decreasing trends. (Source: National Marine Fisheries Service.)

FIGURE 16 Participation in Outdoor Recreation Activities

Partial Indicator Data: Listed Activities



Data source: USDA Forest Service. Coverage: all 50 states. Note: "All Other Land-Based Activities" includes biking in 1994–1995 and 2003–2005, but not in 1999–2001. Technical details: Note that these data do not track the amount of time spent on a particular outdoor activity; rather, they measure the number of different activities an individual engages in during a 24-hour day. Thus, the data do not distinguish between several activities on the same day or on separate days in a given year.

Recreation

As the popularity of our national parks and other recreational areas attests, the U.S. public enjoys outdoor recreation. Our ecosystems offer a diversity of settings in which to engage in a wide range of activities—everything from whitewater rafting in the Rockies, deep-sea fishing off Florida, biking across the vast Midwest plains, or hunting in the Maine woods, to dog sledding in Alaska. Recreation provides enjoyment, health benefits, and even educational opportunities.

- Americans over the age of 16 participated in outdoor recreational activities 58 billion times per year, and almost half (45%) of total recreation occurs in forests. Walking is the most popular activity (23 billion times per year), followed by nature viewing (15 billion times per year) and all other land-based activities (15 billion times per year). Americans participate in water-based activities approximately 5 billion times a year.

In general, participation in outdoor recreation appears to be increasing over the three time periods shown in Figure 16—additional years of monitoring data will be needed to determine if observed increases are part of statistically significant trends. (Source: USDA Forest Service.)

Natural Ecosystem Services—the "Hidden" Services

Other services we receive from our nation's ecosystems are less familiar but no less important. They include such critical natural processes as purification of air and water, regulation of climate and floodwaters, erosion control, pollination, seed dispersal, carbon storage, and renewal of soil fertility. Changes in these natural ecosystem services can affect not only the condition of our environment, but also our ability to obtain more tangible goods and services from the nation's ecosystems on a sustainable basis. At present, the scientific community is wrestling with how best to describe the extent and value of these services and to detect and evaluate changes. Our indicators reflect this need for continued development.

Environmental Information: Challenges and Opportunities

Data Gaps and Challenges

The 2008 report presents a wide variety of valuable information, but critical data gaps affect indicators for all ecosystem types and major reporting categories. Data are inadequate for national reporting for 28 indicators and are only partially adequate for reporting on an additional 32 indicators. In 2006, the Heinz Center's *Filling the Gaps** report presented strategies and estimated costs for addressing ten high-priority data gaps found in the 2002 *State of the Nation's Ecosystems* report. Many of these data gaps remain in the 2008 report, although new data have been acquired for contaminants in shellfish, stream habitat quality, areas with depleted oxygen, freshwater animal communities, and impervious surfaces in urban areas.

> An effective environmental monitoring and reporting system provides information that users need. But doing so requires sustained and expanded support to ensure that monitoring programs can provide the basic information and continued improvement to ensure that the methods and indicators reflect current scientific advances. So that the resources devoted to these activities are applied effectively, it is important to foster a broad view of a "system," from management and policy choices to end user—and to involve a wide range of parties in the oversight of this enterprise.

Information critical to understanding the condition and use of our nation's ecosystems remains unavailable for a number of reasons. Within the federal system, many national-scale monitoring programs have been called on to meet an expanding set of information needs without new funding, or have been subject to ongoing cost inflation without new funding. Important elements of the nation's ecological data collection and reporting system are operated through *ad hoc* arrangements or are carried out by nonfederal entities with *ad hoc* federal support. Often, data gathered for academic research or regulatory purposes does not provide a consistent, national view of ecological trends. Overall, there is no mechanism to determine the most appropriate and highest priority investments in monitoring and reporting capacity.

Many of the 68 indicators that are populated with data in the 2008 report are limited in their ability to characterize ecological conditions fully because of the constraints of existing monitoring programs. For example, 27 of these indicators cannot report on trends over time, often because the data-gathering programs they depend on focus on answering narrowly defined research questions or do not use comparable methods over time. Datasets may be relevant only at national or major regional spatial scales or provide coverage only for specific regions, reducing their utility for state-level planning or national policymaking. In some cases, distributed and diverse monitoring programs produce datasets that are not easily integrated for national reporting. In other cases, data gathering is restricted to selected ecological features (single species or taxa, subsets of habitat types, for example), precluding a comprehensive view of ecosystem condition and use.

Extent and Pattern Data gaps constrain reporting on the extent of key aquatic habitats, including coral reefs, submerged aquatic vegetation, coastal wetlands, rivers, streams, riparian areas, lakes, and reservoirs; data are also not adequate for reporting on the connectivity of streams.

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* The Heinz Center. 2006. *Filling the Gaps: Priority Data Needs and Key Management Challenges for National Reporting on Ecosystem Condition*. See www.heinzcenter.org/ecosystems

Terrestrial systems have fewer data gaps, although data are not adequate for reporting on the area of rare community types, proximity of croplands to residences, or conversions between “natural” and developed lands.

In addition, time trends cannot be reported for many extent and pattern indicators, including shoreline types, the percentage of cropland in the farmland landscape, the size of ”natural” patches, riparian area and land use type, and the extent of grasslands and shrublands, as well as housing density, impervious area and overall extent of urbanized areas. Multiple monitoring programs and variable measurement protocols affect datasets for shorelines types, total cropland, and wetlands. Timing of forest data gathering varies from state to state, reducing the temporal resolution of nationally aggregated data. Satellite-based land cover data do not distinguish between heavily managed and relatively unmanaged lands.

Chemical and Physical Characteristics Reporting on aquatic ecosystems is limited by data gaps for coastal erosion and water clarity. For grassland and shrubland areas, groundwater levels and nitrate concentrations go unreported because of data gaps. Data on carbon storage is limited to a subset of terrestrial ecosystems, so a comprehensive national picture is not yet possible. Farmland soil salinity and levels of toxic contaminants in urban soils and ambient air are also not consistently monitored nationwide.

Some indicators report data only for selected geographic regions; these include dissolved oxygen, nitrate input to coastal waters, and phosphorus in large rivers. Chemical contamination indicators face several data limitations, including lack of time trends and variation in the types of data and benchmarks available for coastal systems, fresh waters and ambient air. Data on stream habitat quality are available nationally, but they are not applicable to specific ecosystems. National-scale data for freshwater acidity may not capture high-acidity episodes, which can have significant ecological effects.

Biological Components All non-native species indicators are affected by data gaps for national-scale reporting, with the exception of freshwater fish and bird populations in grasslands and shrublands. Data are lacking for reporting on at-risk marine species, conservation status of plant species in specific ecosystem types, population trends of invertebrate animals and plants that are at risk of extinction, and “original” species in urbanized areas. Reporting on the status of bottom-dwelling communities is affected by infrequent sampling and regional variation in status assessment, while lack of national-scale monitoring prevents reporting on biota in farmland soils and forest community types with significantly reduced area. Data are scarce for animal mortalities and deformities, except for unusual marine mortality events.

Goods and Services Reporting on aquatic ecosystems is constrained by data gaps for coastal bathing water quality, disease outbreaks related to drinking water or recreational water use, and changes in groundwater levels nationwide. Underlying data for national water withdrawals are affected by state-to-state variation in accuracy and reporting categories, while data for status of commercial fish stocks are limited to a subset of commercially harvested stocks. Data are available for participation in recreational activities in forests and in the nation as a whole, but they are not available for recreation in for farmlands, fresh waters, or grasslands and shrublands, nor are data adequate for national reporting on publicly accessible open space in urbanized areas.

Key Research Needs

From its inception, the State of the Nation's Ecosystems project was designed to provide the best possible set of indicators of the condition and use of ecosystems and to adapt this set over time in response to advances in science and environmental monitoring. For the 2008 report, six new indicators were developed and fifty-seven indicators from the 2002 report were redesigned or refined in order to capture essential ecosystem attributes more accurately.

A "next generation" of indicator refinement will address design challenges that require a combination of time, resources and input from knowledgeable experts, as well as design challenges that require more extensive research. Several high-priority questions about the *State of the Nation's Ecosystems* indicators must be answered:

- Are indicator metrics sufficiently sensitive—on policy- and management-relevant timescales— to capture ecological responses to changing climatic conditions and to assess the sustainability of resource use?
- Do indicators describe chemical contamination and nutrient concentrations at the most useful levels of detail and temporal and spatial scales?
- Can indicator metrics be developed to report on important disturbance patterns despite difficulties in characterizing changes in very long-term patterns (for example, fire frequency) and highly variable phenomena (for example, harmful algal events)?
- Can indicator metrics be developed to characterize native species composition and species condition in human-dominated systems?
- Can landscape pattern indicators be fine-tuned for reporting on exurban development, proximity of roads and open spaces, and fine-scale changes in natural lands and coastlines?
- Can the frequency and resolution of satellite-derived land cover data be improved?

Partners in Progress

Over the decade of the State of the Nation's Ecosystems project's existence, many other complementary indicator or assessment efforts have been initiated. The Millennium Ecosystem Assessment (http://www.millenniumassessment.org), for example, is a global assessment of trends in goods and services provided by ecosystems. The U.S. Environmental Protection Agency (EPA) has released its second *Report on the Environment* (http://www.epa.gov/roe/), which focuses on EPA's legal and policy objectives and is tied directly to that agency's strategic planning process. There are also several "sustainable resource roundtables"—multisector, collaborative efforts that grew out of the Montreal Process Criteria and Indicators for the Conservation and Sustainable Management of Temperate and Boreal Forests. These roundtables, established for forests, rangelands, water resources, and minerals, generally incorporate indicator development or reporting as key aspects of their work. We see many similarities between the basic approaches utilized in these projects and look forward to continued collaboration, refinement, and harmonization of these important efforts.

An Agenda for Continued, High-Quality, Nonpartisan Reporting

There was healthy skepticism in 1997 that it would be possible to pull together the many stakeholders, scientists, and fragmented data sources needed to develop a broad, accurate picture of the state of the nation's ecosystems and how those ecosystems are changing—and to maintain and strengthen the effort over time. Ten years of work and the release of the second *State of the Nation's Ecosystems* report have put that debate to rest.

The State of the Nation's Ecosystems 2008 is an important step in a longer journey toward continued periodic, science-based, and nonpartisan reporting on key aspects of ecosystem condition. Despite the successes so far, much remains to be done

- To increase the availability of key monitoring data
- To ensure that the indicators keep up with scientific advances and changing policy needs
- To connect and reconcile these national indicators with those used by states, local governments, and federal agencies
- To create the institutional capacity to continue this monitoring and assessment effort over the coming decades

Other types of national infrastructure efforts, such as creation of the federal highway system or the capacity for reporting national economic indicators, have required decades of patience, persistence, and a long-term perspective. To cope successfully with the environmental challenges ahead, decision makers and the public need timely, reliable, unbiased, scientifically rigorous information about changes and trends in the state of the nation's ecosystems—that is, a clear window through which we can see where we are and where we are heading. The State of the Nation's Ecosystems project is that window.

To ensure that this vital reporting effort endures, evolves, and matures in a way that best suits our nation's needs, it will be crucial to continue the ongoing dialogue about what is to be reported, the form in which reporting will take place, and the institutional mechanisms to be employed in monitoring and reporting changes in our nation's ecosystems.

Appendix

Environmental Information: A Road Map to the Future Executive Summary

[In June 2008, the Heinz Center released Environmental Information: A Road Map to the Future *as a companion piece to* The State of the Nation's Ecosystems 2008. *The Road Map report describes the type of information system needed for the 21st century and specifies actions that can be taken by Congress, the federal executive branch, and states to establish such a system.]*

The Challenge

The United States is facing unprecedented environmental changes, but decision makers do not have the information they need to understand and respond to these changes in a timely fashion. Current environmental stresses, exacerbated by a changing climate, will produce more rapid and less predictable environmental change, requiring managers to respond quickly and creatively, but funding limitations and a fragmented system limit the ability of the nation's environmental monitoring and reporting infrastructure to meet current and future needs.

- Despite growing environmental challenges facing the United States, the current system of collection and delivery of information about environmental trends is ***unable to meet current and future needs of decision makers.***
- At the national level, there is ***no established set of indicators to serve as benchmarks for judging the nation's progress*** on key environmental matters. The United States has an official suite of indicators for the economy—the environment needs one, too.
- Responsibility for the collection, analysis, and dissemination of the data needed for key policy and decision making is fragmented, resulting in a profusion of ***insufficiently coordinated federal, state, local, and nongovernmental efforts.***

The bottom line: Without leadership from Congress, the executive branch, and states, decision makers will continue to struggle to obtain information, crucial decisions will be poorly informed and thus poorly crafted, and information for accountability purposes will not be available.

The Solution

- ***Formally establish a set of national environmental indicators*** and an open and transparent process for selecting and refining these indicators.
- Use this process to ***drive improvements in environmental monitoring by federal, state, local, and nongovernmental parties***, by carefully aligning monitoring activities so that they meet key decision needs.

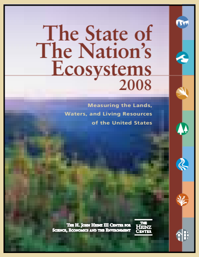
Who Should Lead the Way?

- ***Congress*** should authorize a set of national environmental indicators, as the capstone of a more strategically managed system of monitoring and reporting.
- ***The executive branch*** should create public–private, federal–state forums to involve key decision makers, and should plan, budget, and prioritize investments for building a national system.
- ***States*** should act on the realization that multistate, regional, and national trend-tracking can provide powerful input to many of their decisions.
- Both the ***federal government and states*** should increase the resources devoted to information collection and integration.

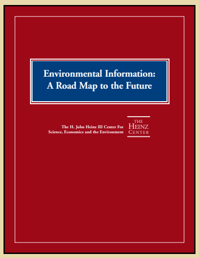
What Is the Time Frame?

Work should begin immediately. Climate change is already modifying the nation's environment, and the information that managers and policymakers need to deal with these growing challenges is not now available. This urgency demands a corresponding rigor and efficiency in conceiving, designing, and implementing a new environmental information system that builds on the monitoring, reporting, and research infrastructure currently in place. The time to act is now.

Related Heinz Center Reports



The State of the Nation's Ecosystems 2008: Measuring the Lands, Waters, and Living Resources of the United States
Contact Island Press (www.islandpress.org) to purchase this book.



Environmental Information: A Road Map to the Future
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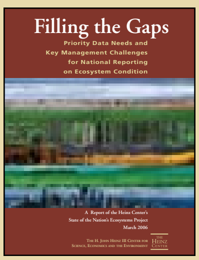

Filling the Gaps: Priority Data Needs and Key Management Challenges for National Reporting on Ecosystem Condition
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